No. 6

Lockheed L-1011 Tristar, HZ-AHJ, accident over international waters near the State of Qatar on 22 December 1980. Report dated 21 February 1982 released by the Presidency of Civil Aviation, Saudi Arabia

SYNOPSIS

At 2312 GMT on 22 December 1980, Saudi Arabian Airlines, HZ-AHJ, a Lockheed L-1011, operating as Flight SV162, experienced an explosive decompression of the cabin while climbing through 29 000 ft over international waters near the State of Qatar. The aircraft had departed Dhahran, Saudi Arabia, and was enroute to Karachi, Pakistan. An emergency descent was initiated and a successful landing was made at Doha International Airport in Qatar. There were 271 passengers and 20 crew members aboard. Two passengers were killed when they were ejected from the aircraft through a hole in the cabin floor which had resulted from the forces of explosive decompression.

The Presidency of Civil Aviation determines that the probable cause of this accident was an in-flight fatigue failure of a main landing gear inboard wheel flange resulting in the rupture of the aircraft's pressure hull and explosive decompression. The failure of the flange was the result of the failure of the B.F. Goodrich Company and the Lockheed Aircraft Company to properly assess the safety hazard associated with the type of wheels installed on aircraft HZ-AHJ.

Contributing to the accident was the lapse of effective quality control procedures by the B.F. Goodrich Company and the failure of the Federal Aviation Administration to provide adequate surveillance of the manufacturer.

1. FACTUAL INFORMATION

1.1 History of the Flight

On 22 December 1980, Saudi Arabian Airlines (SAUDIA) Flight SV162, a Lockheed L-1011, HZ-AHJ, was a regularly scheduled passenger and cargo flight from Jeddah, Saudi Arabia to Karachi, Pakistan with an intermediate stop at Dhahran, Saudi Arabia.

The crew reported for duty at Saudia's Dispatch Office at 1800 GMT (2100L)[1/] after which they briefed for the day's flight. After the briefing, the Flight Engineer, F/E, went to the aircraft and performed the pre-flight check. No abnormalities were noted and upon arrival of the remainder of the crew and passengers, the flight departed Jeddah at 1930. After an uneventful flight, SV 162 landed at Dhahran at 2129.

Sixty passengers deplaned and 87 passengers boarded the aircraft giving a total of 271 passengers and 20 crew members. The maximum passenger load for the aircraft is 279.

After adding 24 450 kg (kilograms) of fuel, the flight was pushed back from its parking ramp at 2230. It then taxied to Runway 34L - taking about 21 minutes due to a lengthy taxi routing; however, brake temperatures were reported to be normal during the taxi sequence.

At 2251, after receiving clearance to Karachi via Amber 1 Airways and to climb to 33 000 ft, Flight Level 330 (FL-330), the aircraft departed Dhahran. The estimated time en-route to Karachi was 1 hour and 52 minutes.

1/ All times herein are Greenwich Mean Time unless otherwise noted.

According to the crew, the departure and climb were normal. The F/O was at the controls and autopilot "B" was engaged with the Area Navigation mode being utilized. The F/E stated that he noted the cabin altitude to be 5 000 ft with a differential pressure about 7.5. Shortly thereafter, there was a loud explosion and the cockpit door flew open.

The Captain stated that he was looking at the altimeter at the time of the explosion and it indicated a climb through about 29 000 ft. The time was 2312.

Immediately after the violent noise and rapid decompression occurred, the Captain took control of the aircraft and began an emergency descent at which time the passenger oxygen masks were manually deployed. Fluid was lost from hydraulic systems A and B and their low quantity lights came on. The number 2 engine driven generator failed, and the left main landing gear door (MLG) warning red light came on. The left hand outboard MLG well door had separated from the aircraft.

The In-Flight Supervisor (IFS) advised the flight crew that there was a large hole in the cabin floor directly over the left MLG, and that the wheel and tire were visible through the hole.

At the time of the explosive decompression, a food service cart was being pulled over the aisle area where the floor rupture occurred. It was thrown up into the air and fell down forward of the hole. A jagged piece of metal, about 3 in by 7 in was propelled into the ceiling above the hole and numerous other pieces of metal and tire rubber were blown around the cabin area adjacent to the ruptured floor area. Two children had been subjected to explosive decompression forces which ejected them out of the aircraft through the hole in the floor. Some other passengers in the area were injured by flying debris. (See Photographs 1 through 4.)

The Captain decided to make an emergency landing at Doha International Airport as it was the closest suitable airport. Bahrain Centre then transferred control of the flight to Doha Control who cleared the flight to land on Runway 34 at Doha. Upon an initial flap selection to 4 degrees, the leading edge slats extended normally but the flaps failed to extend. The flap assymmetry warning light did not illuminate. The Captain stated that he had to maintain left aileron control to remain in straight and level flight. He decided to make a no flap landing and, after being given permission by Air Traffic Control, he dumped 16 000 kg (35 273 lb) of fuel to lighten the load for landing.

During this time, the cabin crew were keeping the passengers calm, demonstrating the crash position and completing the inflight portion of the emergency procedures.

Upon approaching Runway 34, the landing gear was lowered normally and the aircraft landed at 2348.

The Captain states, in part:

> "When I finished fuel dumping I was having Doha in sight. Doha cleared me for a straight in approach runway 16 or runway 34 because the wind was calm. When I intercepted the final approach I found myself about three miles final and 1 500 ft. I said to the Tower I want to go for left down wind for runway 34, he said you are clear to land. Before landing I briefed the IFS I have the gear down we should have no problem in making a normal landing but after touch down, if you see fire or smoke push the evacuation alarm so I will stop the aircraft as soon as I can and then evacuate. But if you do not see fire or smoke wait for my words to evacuate. I touched down safely and stopped the aircraft using maximum reverse and full brake application to stop

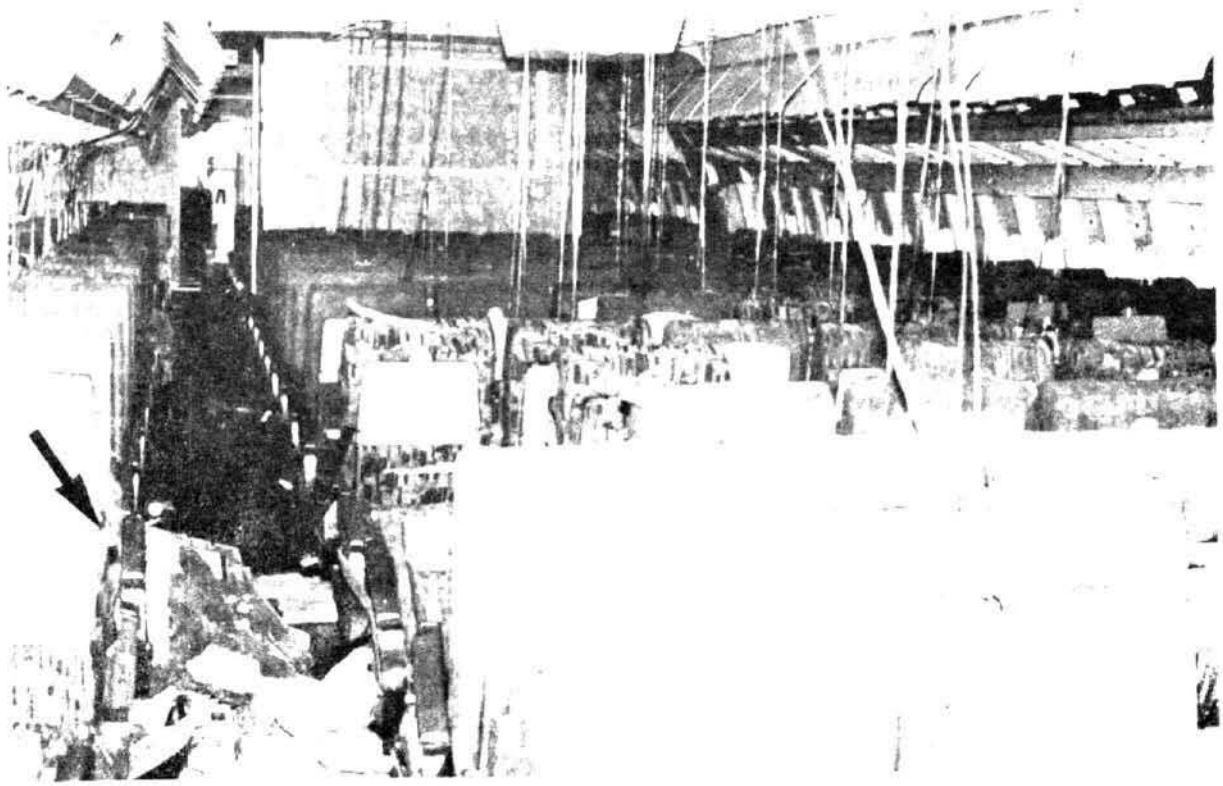

Photo No. 1. View of interior of aircraft Looking forward. Arrow points at hole in floor on the Left side of the aircraft.

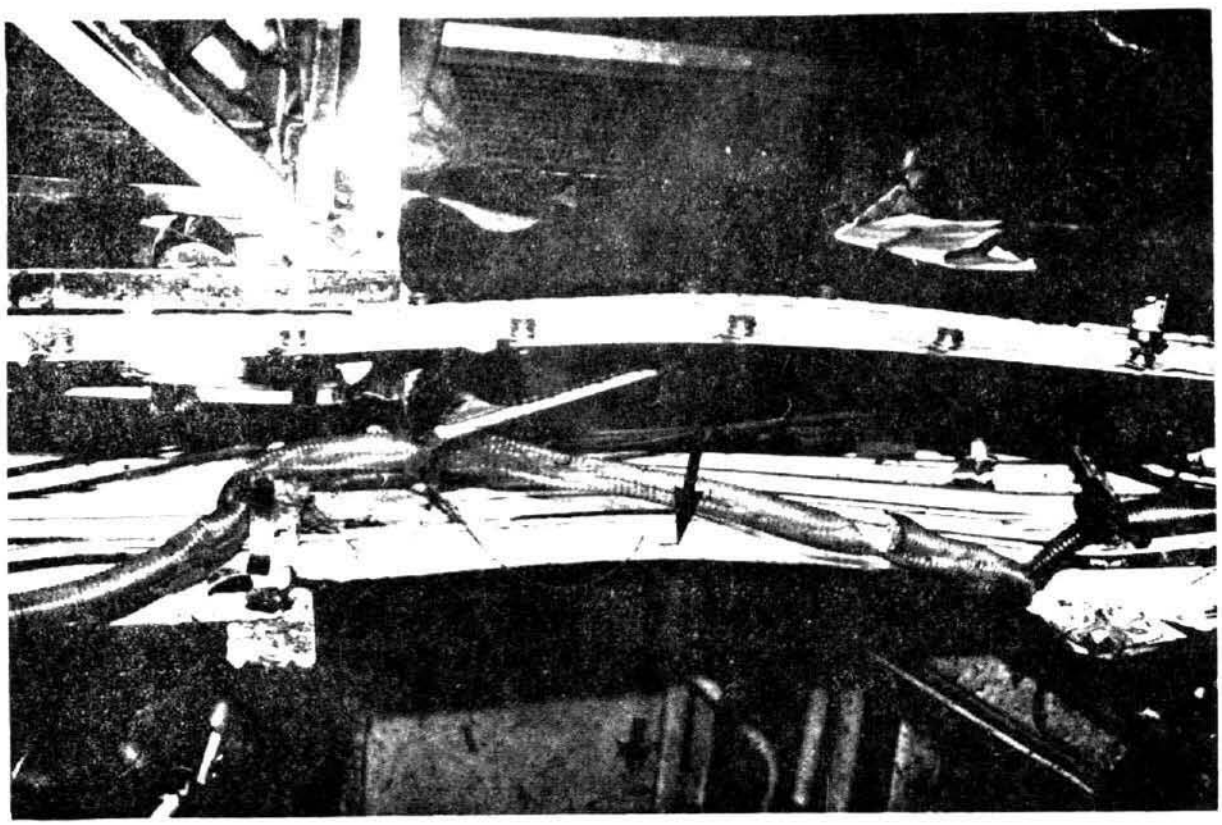

Photo No. 2. Close up View of the area of distruction. Arrow points at left wheel well area.

the aircraft. I pulled in a high speed taxiway. I was looking to see the fire trucks they were almost at the ramp area when I looked out of the window. Then I shut down engine 1 and 3 and command the IFS not to make evacuation by that time the fire trucks and stairs were there. We opened L-1 and L-2 doors by the emergency handle without inflating the slides, because there was no power from No. 2 generator. The engineer started the APU and got it running, but was unable to connect it to the bus. The emergency lights were adequate to get the passengers out except for the last few passengers when we used the flash lights."

The normal egress of the passengers and crew continued with the use of flash lights and lighting provided by the Fire Service vehicles.

The accident occurred in darkness, in good weather, at about 29 000 ft over the Gulf of Bahrain. The latitude was about 24° 25'N and the longitude about 50° 55'E.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	0	2	0
Serious	0	0	0
Minor/None	20	269	

Two children, one 14 year old girl and a 1-1/2 year old boy were ejected from the aircraft while over the Gulf of Bahrain. Their bodies were never recovered. Five other passengers received minor injuries and were taken to a hospital for examination and treatment.

1.3 Damage to Aircraft

The aircraft was substantially damaged.

1.4 Other Damage

None

1.5 Personnel Information

The crew members were qualified and certificated for the flight and had received the training required by current regulations.

1.6 Aircraft Information

Lockheed L-1011-200, S/N 1161 was certificated and maintained in accordance with applicable regulations.

The centre of gravity, 23.3% MAC, was within the prescribed limits for an approach and landing at Doha. Take-off weight was 183 071 kg (332 892 lb). Its landing centre of gravity was about 18.9% MAC.

At the time of the accident, Saudia was using the latest inspection procedures as called for in Goodrich Service Bulletin 370. To accomplish the inspection the 1) wheel halves were cleaned and degreased, 2) paint was stripped with approved stripping solution, and 3) bead seat area was inspected using Eddy Current inspection methods. Saudia was inspecting each wheel at every tire change.

A comprehensive review of the L-1011 wheels and the history of Saudia's corrective actions will be discussed in Section 1.17 of this report.

1.7 Meteorological Information

When the decompression took place, the aircraft was climbing through FL290. The weather was clear with no turbulance and the weather at Doha was clear. The winds were from 260° at 5 kt. The altimeter setting was QNH[2/] 1 017 mb and the temperature was 22°C.

1.8 Aids to Navigation

The airport has VOR/DME as well as an ILS for Runway 34. All navigation aids were functioning properly.

1.9 Communications

There were no communications difficulties.

1.10 Aerodrome Information

Doha International Airport is located at North 25° 15'6" Latitude and East 051°34'0" Longitude. The airport elevation is 38 ft mean sea level (msl).

Runway 34/16 is 15 000 ft long and has 98 ft of stopway for Runway 34 and 49 ft of stopway for Runway 16. Runway 34 has HIRL, HIALS, T-VASI and HST-4[3/].

Doha has a comprehensive Crash/Fire/Rescue (CFR) emergency operating plan which was implemented for the emergency landing.

Fire vehicles responded immediately to the emergency and followed the aircraft until it came to a stop. They then assumed their prescribed positions around the aircraft.

1.11 Flight Recorders

1.11.1 Digital Flight Data Recorder (DFDR)

The aircraft was equipped with a Lockheed 209E, Serial 704 DFDR. It was removed from the aircraft and delivered to the National Transportation Safety Board's (NTSB) laboratory in Washington, D.C. for examination. The recorder had not been damaged; however, it had failed and had printed faulty information.

1.11.2 Cockpit Voice Recorder

The aircraft was equipped with a Fairchild A-100 CVR, Serial Number, S/N, 4083 which was also delivered to the NTSB's Washington D.C. laboratories.

The recorder and its tape were in excellent condition; however, power had been left on the recorder following the accident and the only conversation on the tape was that which occurred after the aircraft had landed (see Appendix L).

1.12 Wreckage and Impact Information

2/ QNH - Altitude above mean sea level based on local station pressure.

3/ a) T-VASI - A visual guidance system for aircraft to ensure proper obstruction clearance and to provide a runway aiming point. It has a one bar system with bisecting longitudinal lines of six lights.
b) HIRL, HIALS and HST-4 are all runway lighting aids.

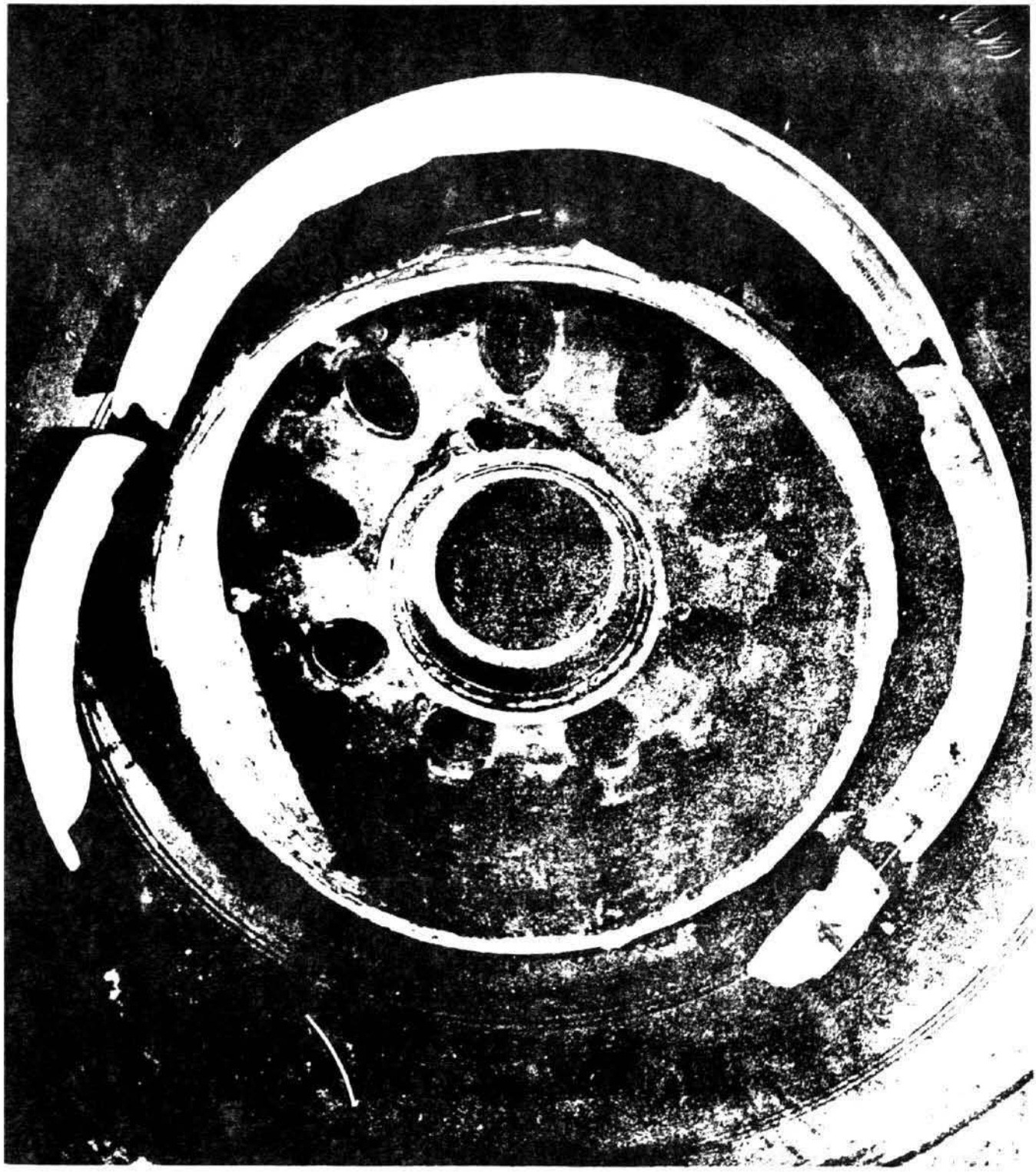

Photo No. 6. View of failed tire and wheel hub with the pieces of failed rim that were located surrounding their approximate positions. Arrow points at position overstamped as a 1323 wheel rim.

1.12.1 Structures and Controls

Examination of the damaged area of the aircraft revealed the floor structure directly above the left wheel well was ruptured causing a 40-in long and 18-in wide hole at Fuselage Station (FS) 1263. The hole was in the area of left side rear seat rows 26 through 28. (See Photographs 4 and 5).

The left hand main landing gear door had separated from the aircraft at its hinges and was missing.

When the floor structure separated, one section had penetrated through the Keelson Beam vertical structure. Three beams located below the ceiling pressure bulkhead from FS 1303 to FS 1363 were damaged. The trailing edge flap torque tubes were damaged and the Aileron Idler Arm under the floor board at FS 1308 was broken. The Aileron Control Rod at FS 1363 was damaged and the floor structure, which had separated, was holding the Aileron Idler Arm and its bracket. The DHC control push rod which is located between the flap angle gear boxes was damaged. The left hand control cable Part Number (P/N) L510403C was damaged and rubbing on the adjacent structure.

Seat tracks were damaged between FS 1363 and 1243. The left hand outboard and centre seats at rows 28, 29 and 30 were also damaged.

1.12.1.1 Wheel Assembly and Landing Gear

Examination of the structure in the area of the missing left main landing gear wheel door revealed that the door hinges were attached to the main aircraft structure. The rivets had sheared. The centre door sheet metal beam had remained intact.

The outboard half of the rim of the No. 2 left hand rear wheel of the main landing gear was missing from the wheel. One 16-in long section was found in the cabin of the aircraft under seat 28B; one 3-in long section was found in the hydraulic service centre; two sections of 30 in and 12 in respectively were found at the departure entrance taxiway to Runway 34L at Dhahran International Airport, and one section was not recovered.

Examination indicated that the wheel flange had completely separated from the wheel rim along the bead set radius. The failed wheel flange was a part of an outside wheel half of an inboard wheel. Its S/N was 185 and it showed a manufacturing date of August 1975.

A review of the maintenance records indicated that all required inspections had been performed. Record search revealed that the failed wheel assembly had a total of 1 200 landings as of 23 December 1980 and 24 landings since the last wheel build-up on 15 December 1980. At the time of the 15 December build-up an Eddy Current inspection had been accomplished.

The outer wheel half and all available pieces of the failed wheel rim were sent to the NTSB's Metallurgical laboratory for analysis and it was determined that the failures were the result of fatigue (see Appendix J).

The Dunlop S/N 0316336 34-ply rated tire had remained on the wheel but was deflated. One section of the tire bead wire bundle was severed and the interior of the tire contained a number of metal fragments. A piece of the tire was found in the cabin area.

1.12.2 Systems and Electrical

1.12.2.1 Hydraulic

The following damage of the hydraulic systems of the aircraft is as follows:

a) System "A" hydraulic suction line was damaged at FS 1303 in the left hand wheel well Hydraulic Service Centre.

b) System "A" hydraulic pressure line was damaged at FS 1303 (left hand wheel well).

c) System "A" hydraulic return line was damaged at FS 1303 (left hand wheel well).

d) System "B" hydraulic return line was damaged at FS 1323 (left hand wheel well).

e) System "B" hydraulic pressure line was damaged at FS 1323 (left hand wheel well).

1.12.2.2 Oxygen

Three hundred and seventy two passenger oxygen masks of the 400 installed had been deployed, (see Photograph 1).

1.12.2.3 Electrical

The following damage to the aircraft's electrical system was noted:

a) Six power cables were sheared under the floor in the cabin at FS 1323. (APU and No. 2 Generator).

b) A large wire bundle at FS 1323 under floor panel of Seat 28B was stretched and many of its wires were severed.

c) The ceiling lights above Seat 28D were damaged.

d) A section of Fire Warning Loop in left wheel well was missing.

The electrical wires that were damaged or severed affected the waste disposal; APU engine fuel control; aft No. 2 lavoratory pump; APU generator sense line and system; passenger compartment service outlet; cabin attendant work light; "A" system hydraulic power indicator; entrance area lights; aft lavoratory No. 3 motor power; APU generator feeder cables and the No. 2 engine generator feeder cables.

1.13 Medical and Pathological Information

Five passengers received minor injuries and were released from the hospital after a medical examination. The bodies of the two children that were ejected from the aircraft were not recovered.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The accident was survivable. The structural integrity of the cockpit and most of the cabin area was not compromised. There were no seat belt failures although the father of the children who were ejected stated that both children were being restrained by seat belts. He stated that one child was in its mother's arms and a seat belt encompassed both the child and the mother and the older child was in a separate seat.

1.16 Tests and Research

1.16.1 Metallurgical Examination

HZ-AHJ's outer wheel half of the aft inboard wheel of the left main landing gear and its failed rim flange were examined by the NTSB's metallurgical laboratory, (see Photograph 6).

Identification marks for the wheel half and wheel assembly were found on the outboard faces of the rim flange pieces. The basic part number for the wheel half was found on the smallest of the flange pieces. The P/N was 10-1323 which identifies a wheel half that is usually used on a 3-1365 wheel assembly "improved wheel". 4/ However, further examination revealed that the middle two digits of "1323" had been restamped and the original part number underneath appeared to be 10-1213. Such a part is to be used on 3-1311-3 wheel assemblies "unimproved wheels" (see Photograph 7).

The examination disclosed three distinct areas of fatigue cracking with features on the remaining portions of the fractures being typical of overload separations stemming from the fatigue zones.

The flange thickness was measured at several points around the circumference of the wheel half and the values obtained were from 0.462 in to 0.472 in. This value included the paint layers.

Examination also disclosed that the bead seat radius from which the fatigue cracks initiated measured to be about 0.46 in (see Appendix M).

1.16.2 Research of the Failed Wheel Flange

The failed wheel flange was a B.F. Goodrich P/N 3-1311-3, sub-assembly to a P/N 1323 and re-identified as wheel flange 3-1365.

The failed wheel flange 1213 or "unimproved wheel" which measured about 0.46 in met the thickness requirements for a wheel manufactured prior 24 June 1975, but did not meet the requirements for those wheels manufactured after that date.

Wheels manufactured after 24 June 1975, should have an increased flange thickness of 0.490 to 0.550 for P/N 3-1365 wheels up to P/N 1404 wheels.

Continued investigation by the investigation team and the U.S. Accredited Representative disclosed that Goodrich wheels labeled P/N 3-1311-3 and P/N 3-1365 were qualified to technical standard order (TSO) requirements for use on L-1011 aircraft having a maximum gross take-off weight of up to 211 377 kg (466 000 lb).

4/ An "improved wheel" is a P/N 3-1365 wheel that has a thicker flange. An "unimproved wheel" is a P/N 3-1311-3 wheel or a 1365 manufactured before 24 June 1975, that has a thinner flange.

The NTSB found that domestic air carriers using L-1011 aircraft had reported a number of fatigue related failures of the P/N 3-1311, unimproved wheels, but the P/N 3-1365 wheels manufactured after 24 June 1975 (improved wheels) had a satisfactory service history. The NTSB stated that Goodrich warranty provisions, the relative service histories, and Goodrich Service Bulletin No. 369 all fostered the belief that the P/N 3-1365 wheels were stronger than the P/N 3-1311 wheels. Consequently, most operators use only the P/N improved 3-1365 wheels on those L-1011 aircraft operating at high gross weights.

The NTSB stated: "Goodrich Service Bulletin No. 369 also states that the thicknesses of P/N 3-1311 wheel outer flanges are 0.450 to 0.510 in. According to engineering drawings submitted to the Safety Board by Goodrich, the specified dimensions for the P/N 3-1311 outer flanges are 0.410 to 0.470 in. We believe that these errors are indicative of lax quality control procedures. The erroneous Service Bulletin information is misleading to the user and could contribute to confusion regarding the strength and durability of those wheels which are selected for use on L-1011 aircraft having higher gross weight configurations. Additional uncertainty as to the actual dimensional characteristics of the P/N 3-1365 wheels is created by the fact that Goodrich has previously indicated that SER:165 are the "same" as SER:185 wheel assembly. This creates a question as to exactly how many wheels with these dimensions are identified as P/N 3-1365 assemblies".

In responding to the NTSB's recommendations and rationale, the FAA stated, in part: quote "The B.F. Goodrich P/N 3-1311-3 and P/N 3-1365 wheels, including the thinner flange P/N 3-1365 wheels, are approved for installation on the heavier airplanes. We have evaluated this approval and have found no significant difference in safety between these parts. The dimensional differences are slight, and considering the typical fatigue failure mode, the increased thickness is not, of itself, significant enough to contribute to the safety of the wheel.

As you know, there are strong indications that corrosion pits initiated the crack that caused the subject wheel failure. Corrosion has been present in many of the cracked or failed wheels from L-1011 aeroplanes that have been returned to B.F. Goodrich or Lockheed for analysis. Once a surface anomaly such as a corrosion pit develops, and these can develop at any time during the wheel service life, a fatigue crack can be expected to initiate and grow from that anomaly. The minor difference in flange thickness is an insignificant factor when this phenomenon occurs.

Federal Aviation Administration (FAA) specialists have been working with specialists from Lockheed and B.F. Goodrich in an effort to investigate the crack propagation characteristics of a thinner flange wheel on a heavier aeroplane once a detectable fatigue crack is present. The purpose of the investigation is to determine the appropriateness of present in-service inspection intervals. Enlarged photographs of the fracture surface of the subject failed wheel have been compared with the fracture surfaces of four other wheels that had been returned to Lockheed for analysis prior to the subject failure. In all cases, "marker bands" are apparent that can be correlated with the number of landings. Fractographic analysis shows that, for typical wheel failures originating from a surface anomaly such as corrosion pit, which would be the most severe case of stress concentration, inspection using appropriate procedures at every tire change will allow several inspection opportunities to detect a crack prior to wheel flange failure on the thinner flange wheels, even on the heavier aeroplanes.

Therefore, we have concluded that appropriate flange inspection procedures, including method and period, are the key factors in preventing future wheel flange fatigue failures on L-1011 aeroplanes. Given the proper inspection, the differences in flange thickness are insignificant to safety. Moreover, if a proper inspection programme is not implemented, the differences in flange thickness would not significantly forestall failure. Since we do not find the differences in flange thickness significant to safety, we are unable to justify the initiation of the action recommended, i.e. flange wheels measurement or removal of wheels with thinner flanges" unquote.

In answer to NTSB's statement about "lax quality control procedures", the FAA responded:

Quote "Upon return of the failed wheel to your metallurgical laboratory in Washington, DC, we observed that the outboard wheel half P/N 10-1323 had been stamped over a previously stamped P/N 10-1213.

As soon as we saw the part number overstamping, i.e. part renumbering on the subject wheel, we requested our Great Lakes Region manufacturing specialist to initiate an investigation at B.F. Goodrich. Our manufacturing specialist visited the B.F. Goodrich plant on 30 December 1980, and, as reported at the joint FAA/NTSB/ATA meeting in Atlanta, GA, on 31 December 1980, he found that the part renumbering was covered by appropriate engineering orders which our review has shown to be appropriate. The error with respect to identification of the P/N 3-1311-3 cross-section shown on B.F. Goodrich Service Bulletin No. 369, which confused both the FAA and NTSB investigators at the outset, has no relationship to the B.F. Goodrich quality control system. In the service bulletin figure, B.F. Goodrich erroneously labelled the outboard flange of the P/N 3-1311-3 wheel with the inboard flange dimensions. We do not find that the errors in the service bulletin are indicative of lax quality control procedures at B.F. Goodrich. Also, since we have concluded that there is no safety significance to the small differences in flange thickness through the change in P/N's 3-1311-3 to 3-1365, we do not find that the confusion in part numbers could have contributed to the subject wheel failure.

Notwithstanding the above, consistent with your recommendation, we completed a special Quality Assurance System Analysis Review (QASAR) audit of the B.F. Goodrich wheel manufacturing facility at Troy, Ohio, on 12 through 14 January. Emphasis was placed on reviewing the production and quality control procedures applied to the manufacture of wheels for L-1011 airplanes. The QASAR team leader has advised that there were no safety significant deficiencies found that could have contributed to the subject wheel failure, or that would affect the safety of wheels being manufactured at the facility" unquote. (See Appendix J.)

It should be noted that Saudia had been having problems with the unimproved wheels for a number of years prior to this accident. Saudia had not had problems with improved wheels. (See Section 1.16.3 and Appendix I.)

1) At the 30 December 1980, FAA/NTSB/ATA meeting in Atlanta the following pertinent facts were revealed:

a) TWA had eliminated the use of the 1365 unimproved wheels because of web area problems. They had experienced 30 unimproved wheel failures by flange separation. They also discovered that the recommended Goodrich Eddy Current inspection block did not properly cover the flange curve where the maximum stress was concentrated.

b) EAL discontinued the use of the unimproved wheels because of flange failures and because of cracks developing in the fuse plus area. As of the last week in December 1980, EAL had experienced 56 failures of the unimproved wheels. Thirty-five failures had occurred on operating aircraft and the remainder of the failures had been discovered using Goodrich's recommended inspection.

c) AIR CANADA had experienced 8 failures of the unimproved wheels. They replaced all of their wheels with improved wheels and have had no further failures up to the December meeting.

d) PAA only uses the improved wheels and had not experienced any problem.

It should be noted that B.F. Goodrich stated at the meeting that if the unimproved wheel was used on heavy L-1011 aircraft the wheel warranty would be reduced by 50 per cent.

1.16.3 Research of Saudia's Experience with L-1011 Wheel Fractures

Saudia's records revealed that on 25 December 1978, Saudia had contacted Lockheed stating that they had experienced 6 wheel failures in 2 months. Lockheed, in turn contacted B.F. Goodrich requesting if other operators had experienced similar failures and requested immediate action, "in view of the airworthiness implications".

On 28 December 1978, after an exchange of wires, Saudia's Vice President of Technical Services (VPTS) wired Lockheed's VP of Customer Service stating that the wheel failures constituted a serious safety problem. The following is a copy in part, of the wire:

"AA THE REFEKENCE 1 SITA APPRISED LCC OF RECENT L-1011 WHEEL FAILURES IN SV'S OPERATIONS. DURING THE REF. 3 MEETING IT BECAME EVIDENT THAT SIMILAR PROBLEMS HAD BEEN IN EXISTENCE WITH OTHER OPERATORS. SAUDIA CONSIDERS THESE FAILURES A SERIOUS SAFETY HAZARD TO L-1011 OPERATION. ACCORDINGLY, WE TAKE STRONG EXCEPTION TO LOCKHEED'S POSITION AS EXPRESSED IN THE REF. 2 SITA.

THAT QTE NO L-1011 WHEEL FAILURE TO DATE ON RECORD HAS CAUSED AN OPERATIONAL PROBLEM UNQTE. IF DURING WALK-AROUND FRACTURED WHEELS ARE DISCOVERED, THIS, ELLIOT, IS IN OUR DEFINITION, A SERIOUS PROBLEM AND DOES IMPACT THE OPERATIONS. WE CAN CONSIDER OURSELVES FORTUNATE THAT SUCH FAILURES DID NOT RESULT IN MORE SERIOUS CONSEQUENCES.

BB AS SAUDIA TO DATE DOES NOT HAVE LABORATORIES FOR METALLURGICAL ANALYSIS, WE HAVE ARRANGED WITH LUFTHANSA TO DO THIS ON OUR BEHALF. THEIR PRELIMINARY ANALYSIS SHOWS STRAY SHOT PEENING AND/OR UNDIMENSIONED BEAD SEATS AS CONTRIBUTING FACTORS FOR THESE FRACTURES. FROM OUR RECORDS IT APPEARS THAT THE MAJORITY OF THESE FAILURES OCCURRED WITH WHEELS HAVING 75 SERIAL NUMBERS AND WITH 1 500 OR MORE LANDINGS.

CC IN THE INTEREST OF SAFETY WE HAVE/ARE IN THE PROCESS OF TAKING ALL WHEELS THAT ARE SUSPECT OUT OF SERVICE. THIS IS EXPENSIVE, CAUSES OPERATIONAL PROBLEMS BUT IN THE INTEREST OF SAFETY, THERE DOES NOT SEEM TO BE AN ALTERNATE.

DD I AM REQUESTING THAT LOCKHEED PUT UTMOST EFFORT INTO RESOLVING THIS PROBLEM WITH HIGHEST PRIORITY."

During the ensuing years from 1978 until June 1980, there were numerous exchanges of letters and messages between Lockheed, Saudia and Goodrich regarding the wheels. Finally, on 21 June 1980, Saudia sent a message to Lockheed that they had recently experienced 4 more wheel failures and stated, in part:

"THESE WHEELS ARE OF THE 75 MFG SUSPECTED WHEELS REMOVED FROM SERVICE LATE 1978 PD THESE WERE RETURNED BACK IN SERVICE AFTER RECCO AND CONFIRMATION FROM BFG THAT THESE WHEELS ARE SAFE TO PUT IN OPERATION AND BFG WILL REPLACE ANY FAILED WHEEL ON WARRANTY BASIS PD

CC. WE CAN CONSIDER OURSELVES FORTUNATE THAT SUCH FAILURES DID NOT RESULT IN MORE SERIOUS CONSEQUENCES PD WE ARE SURPRISED AND DISAPPOINTED THAT AFTER ADVISING EVEN LCC RE THIS PROBLEM LITTLE POSITIVE ACTION IS TAKEN TO PREVENT REOCCURRENCE PD ITS A DESIGN AND/OR PRODUCTION PROBLEM. WE CANT TOLERATE THE CONTINUED POTENTIAL FOR FAILURE/FRACTURING OF WHEELS TO HAPPEN DURING TAKE OFF OR LANDING.

DD. IN THE INTEREST OF SAFETY WE INSIST TO TAKE ALL WHEELS, 1975 MFG OUT OF SERVICE AND SEND THESE BACK TO BFG FOR NO COST EXCHANGE WITH IMPROVED WHEELS PD THIS MAY CAUSE OPERATIONAL PROBLEMS TO SV BUT IN THE INTEREST OF SAFETY THERE DOES NOT SEEM TO BE ANY ALTERNATIVE.

EE. PLS PUT UTMOST EFFORT INTO RESOLVING THIS PROBLEM WITH HIGHEST PRIORITY PD"

On 27 June 1980, Lockheed responded stating, in essence, that the reported failure modes of the wheels did not constitute an aviation safety hazard provided that proper maintenance procedures were utilized.

It should be noted that prior to the time of the accident Saudia was using all the maintenance procedures recommended by Goodrich and Lockheed.

It should also be noted that Goodrich representative visited Saudia's main maintenance facility prior to the accident and observed the inspection procedures.

1.17 Other Information

1.17.1 History of Selected B.F. Goodrich Service Bulletins relating to Main Landing Gear Wheels

On 8 June 1979, B.F. Goodrich issued Service Bulletin No. 370 which was applicable to all 3-1311-3 wheels and all 3-1365 wheels up to S/N 1404. The reason for this bulletin was to notify all operators that a number of flange failures had occurred. The bulletin gave instructions of how to detect possible separations by using accepted inspection techniques. It also recommended shot peening and anodizing as described in Service Bulletin No. 369. (Appendix F).

On 16 July 1979, Service Bulletin No. 369 was issued to give instructions to extend the life of 3-1311-3 and 3-1365 wheels by shot peening. It also called for anodizing the wheel surfaces to reduce the potential for corrosion.

On 5 February 1981, B.F. Goodrich issued Service Bulletin No. 393 which was applicable to the accident aircraft. It stated that there had been a number of incidents of in-service separation of portions of the main landing gear wheel flange and that its purpose was to define inspection standards. It was revised on 20 February 1981 to better define its inspection procedure.

On 12 February 1981, B.F. Goodrich issued Service Bulletin No. 394. Its purpose was to ensure that its users could properly identify the 3-1365 wheels. It states, in part:

"Reason

The 3-1365 wheel assembly was originally configured identically to the 3-1311-3 wheel assembly. Subsequently the outboard wheel half flange was increased to improve in-service fatigue life. A previously issued Service Bulletin (No. 3-1311-3/3-1365-32-1, BFG No. 369) led to confusion in determining outboard wheel half flange thickness by the use of wheel assembly serial numbers rather than wheel half part number and change letter."

1.17.2 History of Selected Lockheed L-1011 Service Bulletins and Airworthiness Directives relating to the Main Landing Gear Wheels

Subsequent to the fact-finding of the field investigation, Lockheed Service Bulletin No. 093-32-079 of 20 November 1980, was reviewed. It had no effect in this case, as the SB with revisions was not applicable to the operator of HZ-AHJ. The Bulletin was a modification by service kit to the main landing gear assembly required for higher gross weight take-offs, and showed that different landing gear components (including wheels) were required, and that the rework would have been the manufacturer's responsibility at the factory in the case of HZ-AHJ.

On 5 February 1981, Lockheed issued Service Bulletin No. 093-32-184. Its purpose was to instruct its L-1011 users to inspect the main landing gear wheels of all of their L-1011 aircraft in accordance with B.F. Goodrich Service Bulletin 393. It stated that the work defined in the Goodrich Bulletin required an Eddy Current inspection for cracks in the area of the flange of each wheel half. The Lockheed bulletin called for the inspection to begin not later than 30 days after receipt of its bulletin and a repetitive inspection schedule at each tire change or every 4th tire change (Appendix G).

On 25 March 1981, Lockheed issued Service Bulletin No. 093-032-185. Its purpose was to prolong the wheel life of B.F. Goodrich wheels on L-1011 aircraft. It states, in part:

"Reason

This Lockheed Service Bulletin, 093-32-185 is intended to prolong wheel life. It is recommended that the outboard flange thickness be determined by direct measurement on 3-1365 Wheel outboard half P/N 10-1323 below Change G and that wheels found to have flange thicknesses less than 0.490 inch not be used on aeroplanes operating at gross take-off weights (GTOW) above 430 000 lb (430 K). Furthermore, it is recommended that, depending on inspection results, wheel halves be reidentified in accordance with B.F. Goodrich Service Bulletin 3-1365-32-4 (BFG No. 394).

The above measures will separate the currently identified 3-1365 Wheel halves into two distinct and easily identifiable categories and will provide for a more rational use of these wheel halves relative to aeroplane gross weight in order to minimize operational stresses in the flange. It is desirable to keep operating stresses as low as practical in order to prolong wheel life. The thinner flanges have higher stresses than thicker flanges for the same ground applied gear loads and same inflation tire pressures. Since the operating gross weights have an effect on ground loads and specified tire inflation pressures the restriction of the use of flanges with thicknesses below 0.490 in to aeroplanes operating at gross take-off weights at, or below, 430 000 lb will limit the operating stresses on thinner flanges.

It is recommended that the 3-1365 Wheel outboard half P/N 10-1323 below Change G be inspected per this service bulletin. It is also recommended that 3-1311-3 Wheels be removed from aircraft with a GTOW of more than 430 K and be limited to use on aircraft with a GTOW of 430 K or less."

On 7 April 1981, an Airworthiness Directive was issued to "prevent possible failures of the main landing gear wheels" of Lockheed L-1011 aircraft. It called for the inspection of Goodrich main landing gear wheel assemblies to be made in accordance with Goodrich Service Bulletins (Appendix H).

2. ANALYSIS

The flight crew was properly certificated and qualified in accordance with existing regulations. The aircraft was properly certificated and was maintained in accordance with existing regulations and procedures. There were no significant uncorrected discrepancies in the aircraft's maintenance log.

The evidence points quite clearly to the cause of the accident being the fatigue failure of a main landing gear wheel flange, part of which penetrated the aircraft pressure hull resulting in explosive decompression. The main effort in the investigation was, therefore, directed towards establishing the circumstances which resulted in such a failure taking place. In this regard, the investigation sought to determine: 1) the adequacy of the manufacturer's decision criteria and actions, 2) the effectiveness of the U.S. Federal Aviation Administration's surveillance and rationale and, 3) the adequacy of the airline's maintenance procedures.

Initially, the probable sequence of events leading to the failure of the wheel and the explosive decompression was examined. Evidence indicated that at some time during the life of the wheel assembly, a fatigue crack occurred in the rim which was not detected although it was inspected in accordance with established procedures.

Operational stresses finally resulted in initial separations of two pieces of the rim during the turn onto the take-off runway at Dhahran on the day of the accident. However, these separations were not of the magnitude to immediately result in complete failure of the rim and loss of tire pressure.

During the climb to cruise altitude, the pressure within the tire produced a pressure differential sufficient to apply enough forces to cause the failure of the remaining portions of the rim. This forced the bead of the tire over the jagged portion of the wheel flange. The ensuing explosive release of the gas within the tire projected one part of the rim through the bulkhead into the hydraulic compartment and one part of the rim through the floor and into the cabin.

The blast was sufficient to distort the cabin floor inward before the floor failed. This resulted in metal debris scattering throughout the cabin adjacent to the ruptured area.

A serving cart close to the forward edge of the ruptured floor area was lifted about 10 in and propelled forward.

Review of the flight crew's actions immediately after the occurrence indicates that the aircraft was flown in accordance with Saudia's prescribed procedures. Both the cockpit and cabin crew demonstrated a high level of competence which resulted in the aircraft being landed and the passengers being deplaned without further injury.

2.1 Adequacy of Manufacturers Decision Criteria and Actions

Review of the extensive communications generated over a period of years by Saudia regarding the failures of the 3-1311-3 (unimproved wheels) indicates that the failure problem primarily existed with these wheels and not with the improved wheels. As early as 1978, Saudia stated in a wire to Lockheed's Vice President of Customer Service that they had recently had a meeting with other carriers and "it became evident that similar problems had been in existence with other carriers". The series of communications over the years until the date of the accident is extensive and leaves no doubt of Saudia's opinion that the unimproved wheels were not adequate for their aircraft.

The responses to Saudia from both the Goodrich and Lockheed companies indicated that their concern was more the inspection of the wheels than the adequacy of the wheels themselves for service. In a message from Lockheed to Saudia on 26 December 1978, Lockheed states, "No L-1011 wheel failure to date on record has caused an operational problem, and the fractures have been found on walk-around or inspection". Such a reply to an urgent request from Saudia that an operational problem existed is difficult to comprehend.

On 28 December 1978, a message from Saudia to Lockheed stated, in part "In the interest of Safety we have/are in the process of taking all wheels that are suspect out of service...". In answer to this Lockheed and Goodrich both re-emphasized the inspection process and Lockheed stated that they had no wheel failures on record which were involved with situations that had affected aircraft safety.

In reviewing the communications up to this date, it is obvious that both Lockheed and Goodrich were aware of Saudia's problems with the wheels, yet they kept emphasizing the need for proper inspections although Saudia was complying with their inspection criteria. Therefore, it should have been obvious that the problem lay in the improvement of or the restriction on use of the product and not with the carrier's inspection methods. Also both Lockheed and Goodrich were aware of forces generated in an in-flight wheel explosion and the safety hazards associated with such an occurrence, yet it seems as if they were not too concerned about such a probability. Such apparent lack of concern is one of the primary ingredients to the cause of this accident.

The explosive failure of a tire either in flight or on the ground has been a well-documented serious aviation hazard and has caused numerous serious and fatal accidents. The many operational precautions that aircraft manufacturers have made in this respect is evidence of the concern of the aviation industry.

Until the accident occurred, Saudia continued to notify and question Lockheed and Goodrich about their L-1011 wheel problems and these companies continued to respond in the same manner.

Again, in June 1980, Lockheed stated that "the wheels did not constitute an aviation safety hazard provided that proper maintenance procedures were utilized". Since Saudia was using the prescribed procedures and were still having failures, their only solution seemed to be to replace all light wheels with the heavy wheels with which they were not experiencing problems.

In November 1980, Lockheed issued a Service Bulletin 093-32-079 which was not listed as applicable to Saudia. However, it inferred that heavy weight aircraft should have the improved wheels since it called for service kit modifications of the landing gear assembly including improved wheels for such aircraft. Since the Service Bulletin showed no direct applicability to HZ-AHJ, the change would have been incorporated at the factory. The question arises as to why both Lockheed and Goodrich continued to inform Saudia that the unimproved wheels were suitable for the heavy weight aircraft, yet issued a service kit to retrofit heavy weight aircraft with improved wheels as part of the kit.

An additional ingredient fostering confusion was the labelling of the failed flange to indicate that it was an improved wheel versus an unimproved wheel. This gave Saudia the impression that they were operating with an improved wheel thereby engendering false security. This also indicates a lapse of adequate quality control procedures at Goodrich, a fact which was contributory to the accident.

Following the accident, both Lockheed and Goodrich issued numerous bulletins regarding inspection standards and inspection frequencies. It is interesting to note that Lockheed's SB 093-032-185 states, in part, "The thinner flanges have higher stresses than thicker flanges for the same ground applied gear loads and same inflation tire pressures. Since the operating gross weights have an effect on ground loads and specified tire inflation pressures the restriction of the use of flanges with thicknesses below 0.490 to aeroplanes operating at gross take-off weights at, or below, 430 000 lb will limit the operating stresses on thinner flanges." It continues to state, "It is also recommended that 3-1311-3 wheels be removed from aircraft with a GTOW of more than 430K and be limited to use on aircraft with a GTOW of 430K or less".

This is exactly what Saudia had been trying to do since they began to have problems with the unimproved wheels, yet Lockheed and Goodrich kept maintaining that the wheels were adequate for the heavier aircraft.

The Presidency realizes the benefits of the intelligence available for retrospect observations, but, in this case, such intelligence was clearly available to both Lockheed and Goodrich before the accident occurred. Therefore the Presidency concludes that both Lockheed and Goodrich had sufficient information to make a proper evaluation of the wheel problem and to take appropriate actions prior to the occurrence of the accident. If such actions had occurred, the accident would have been avoided.

2.2 FAA Surveillance and Actions

FAA's role in this accident relates to the adequacy of their surveillance. It is believed that adequate surveillance would have detected the difficulties associated with the unimproved wheels prior to the occurrence of the accident. Yet such a discovery was not the case. In fact, even after the accident, in their answer to the Safety Board's recommendations, the FAA states that they did not find the differences in flange thickness significant to safety. This statement was made even though the FAA was aware of all the problems associated with the unimproved wheels and the dangerous safety hazard of an in-flight failure. The basis for their reasoning, however justified, is not apparent if it applies to the use of unimproved wheels on heavy aircraft. Also in view of Lockheed S.B. 093-032-185, it becomes apparent that Lockheed shares the view that the unimproved wheels are not adequate for the heavy L-1011 aircraft.

The Presidency is aware of the many difficulties that the FAA is exposed to in regard to the surveillance of the extensive aviation industry within the United States and the fine and justified reputation that the FAA holds in the world's aviation community. However, in this case, it is believed that the FAA failed to monitor the manufacturer adequately.

2.3 Adequacy of the Airline's Maintenance Procedures

It is obvious that the airline failed to discover the progression of fatigue during the Eddy Current tests immediately preceding the accident. There is no doubt that fatigue had started prior to these tests. Therefore there could be only two reasons why the tests did not detect the fatigue, those being 1) the test was not 100 per cent reliable and/or 2) Saudia was not conducting the tests properly.

Reference to prior and post-accident investigative findings indicate that Saudia was following the procedures called out by the manufacturer. In fact, the manufacturer had reviewed their inspection process at their maintenance facility. Inspection showed that Saudia's inspections exceeded those recommended by the manufacturer. Therefore, it is concluded that the pre-accident inspections called for by the manufacturer did not result in the capability of 100 per cent detection of fatigue. Such a conclusion is reinforced by similar type failures occurring on U.S. carrier aircraft after manufacturer's prescribed inspections had been accomplished.

In conclusion, this is another accident that could have been avoided if the very visible clues along the way had been seriously regarded, evaluated and acted upon promptly and properly.

3. CONCLUSIONS

3.1 Findings

1. The aircraft was properly certificated and had been maintained in accordance with approved procedures.

2. The flight crew was properly certificated and qualified for the flight.

3. Portions of a left inboard main landing gear wheel flange failed as the result of fatigue and separated while the aircraft was turning onto the take-off runway at Dhahran, Saudi Arabia.

4. Complete fatigue failure of the rim occurred while in flight with gear retracted at about 29 000 ft over international waters near the State of Qatar.

5. A successful landing was made and normal egress of the passengers and crew took place.

6. The forces generated at the time of the failure propelled portions of the rim into the cabin rupturing the pressure hull which resulted in explosive decompression.

7. Two children were expelled from the aircraft during decompression. This resulted in their deaths.

8. The aircraft incurred extensive structural damage during decompression. There also was damage to the hydraulic, electrical and flight control systems.

9. The performance of the flight deck crew and flight attendants was commendable.

10. The failed wheel rim on the aircraft was manufactured by the B.F. Goodrich Co. and its original part number was P/N 10-1213; however, it had been over-stamped to indicate that it was a P/N 10-1323.

11. The P/N 10-1323 is normally part of the P/N 3-1365 wheel assembly (improved wheel) and the P/N 10-1213 is normally part of the P/N 3-1311 wheel assembly (unimproved wheel).

12. Saudia had been having a significant number of fatigue-related failures of the P/N 3-1311 wheels, but had not had problems with the P/N 1365 improved wheels manufactured after 1975.

13. The failed wheel rim had been manufactured prior to the strengthening changes made to the P/N 1365 wheels.

14. The problems that Saudia had been having with the "unimproved" wheels had been relayed to the Lockheed Aircraft Company and the B.F. Goodrich Company. Problems on the subject had taken place over a two-year period prior to the accident.

15. The problems with the unimproved wheels were also experienced by other carriers to the degree that some carriers discontinued their use.

16. Both Lockheed and Goodrich continued to state that proper maintenance procedures would alleviate the problem.

17. Prior to the accident, Saudia was utilizing all the procedures recommended by both Lockheed and Goodrich as it related to the inspection of the wheels.

18. After the accident, Lockheed issued a Service Bulletin specifying the use of heavy wheels on heavy weight aircraft.

19. The U.S. FAA failed to supervise the manufacturer of the wheels adequately. Lockheed and B.F. Goodrich failed to properly assess and take corrective action after becoming aware of Saudia's problem with the unimproved wheels.

3.2 Probable Cause

The Presidency of Civil Aviation determines that the probable cause of this accident was an in-flight fatigue failure of a main landing gear inboard wheel flange resulting in the rupture of the aircraft's pressure hull and explosive decompression. The failure of the flange was the result of the failure of the B.F. Goodrich Company and the Lockheed Aircraft Company to properly assess the safety hazard associated with the type of wheels installed on aircraft HZ-AHJ.

Contributing to the accident was the lapse of effective quality control procedures by the B.F. Goodrich Company and the failure of the Federal Aviation Administration to provide adequate surveillance of the manufacturer.

4. SAFETY RECOMMENDATIONS

As the result of this investigation, the U.S. NTSB made a series of safety recommendations to the U.S. FAA. These recommendations with the FAA's response are reflected in Appendix J of this report.

ICAO Note: Photos 3, 4, 5, 7 and Appendices B to M were not reproduced.

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APPENDIX A

NOTIFICATION AND FORMATION OF THE INVESTIGATION

This accident occurred over international waters, however, the aircraft landed at Doha Airport, State of Qatar. In accordance with Chapter 5, Section 5.3 of Annex 13 to the Convention on International Civil Aviation, the Kingdom of Saudi Arabia conducted an investigation. The United States dispatched an Accredited Representative and advisors to the scene of the accident to assist in the conduct of the investigation.

Upon the arrival on scene, the Investigator-in Charge held an organizational meeting and investigative groups were formed for the airworthiness and operational aspects of the accident.

In accordance with Chapter 6, Section 6.1 of Annex 13 to the Convention on International Civil Aviation the report of this investigation was sent to the United States of America for review by the U.S. Accredited Representative. The substance of his comments is included in this report.